APPENDIX A

INVENTORY CONCEPTUAL MODEL

APPENDIX A

Inventory Conceptual Model Abstract

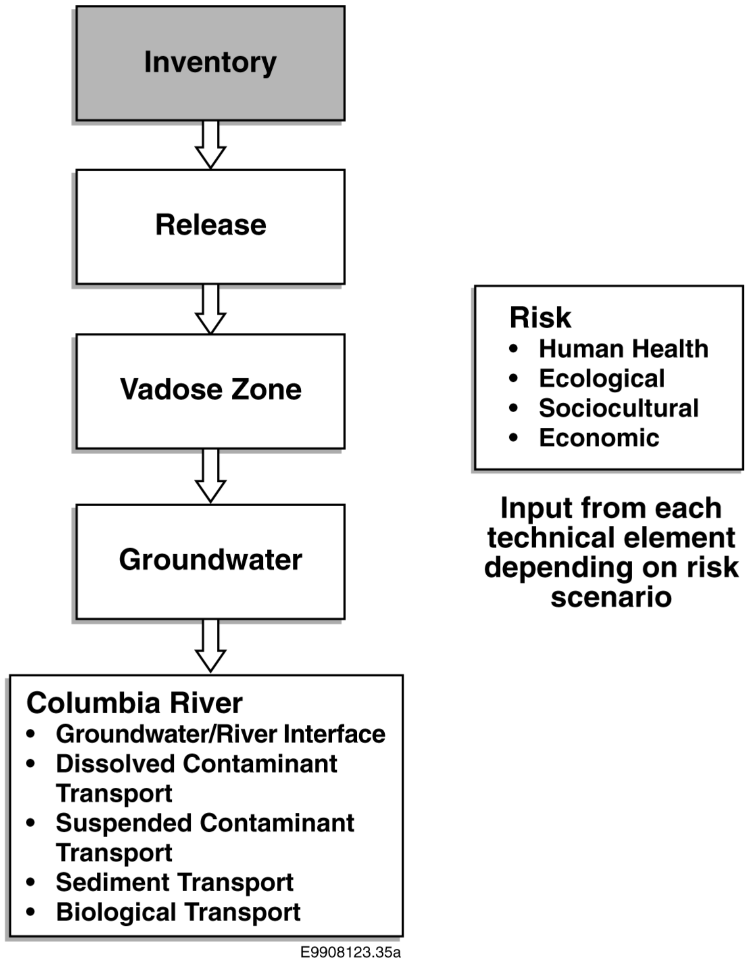
The objective of this appendix is to describe the inventory conceptual model developed for use in the System Assessment Capability (SAC), Rev. 0.

Output from the inventory element will include estimates of the spatial and temporal distribution of contaminants for the various waste disposal and contaminant release locations on the Hanford Site to allow feasibility testing of the SAC (Rev. 0) and to complete an initial assessment of risk and impact from Hanford Site waste. The data from this element feed into the release technical element (Figure A-i).

The inventory technical element will assemble data from numerous databases, previous investigations, and inventory modeling done for the Hanford Site. Inventory databases that will be drawn from include, but are not limited to, the Waste Identification Data System (WIDS), Solid Waste Information and Tracking System (SWITS), Environmental Release Summary (ERS), and Tank Waste Information Network System (TWINS). In the past, estimates of waste inventory have also been developed through modeling approaches that have evaluated process streams and waste generation using historic site records as a starting point to estimate waste volumes and concentrations of the contaminant inventories. The critical task of the inventory element will be to resolve the discrepancies between the various methods and the results of the various approaches to inventory definition to identify the characteristics of waste placed at various waste sites and the time of the placement.

Output from the inventory element will be aggregated by location and waste type. The results will include information aggregated to the 100 Areas, the 300 Area, and both the 200 East and 200 West Areas. Inventory will be aggregated by waste type, including estimates for liquid discharges, solid waste, tank salt cake and sludge, residual wastes, glass waste, graphite cores, and reactor compartments. The effort will focus on four mobility classes of radionuclides and two chemical constituents of concern. The four mobility classes will range from those shown to be highly mobile to highly immobile under conditions observed at the Hanford Site. Inventory information on other radionuclides and chemicals will be obtained through data gathering and modeling if it can be done at no additional cost at this time.

Figure A-i. System Assessment Capability System Conceptual Model.



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INVENTORY CONCEPTUAL MODEL

A.1 BACKGROUND

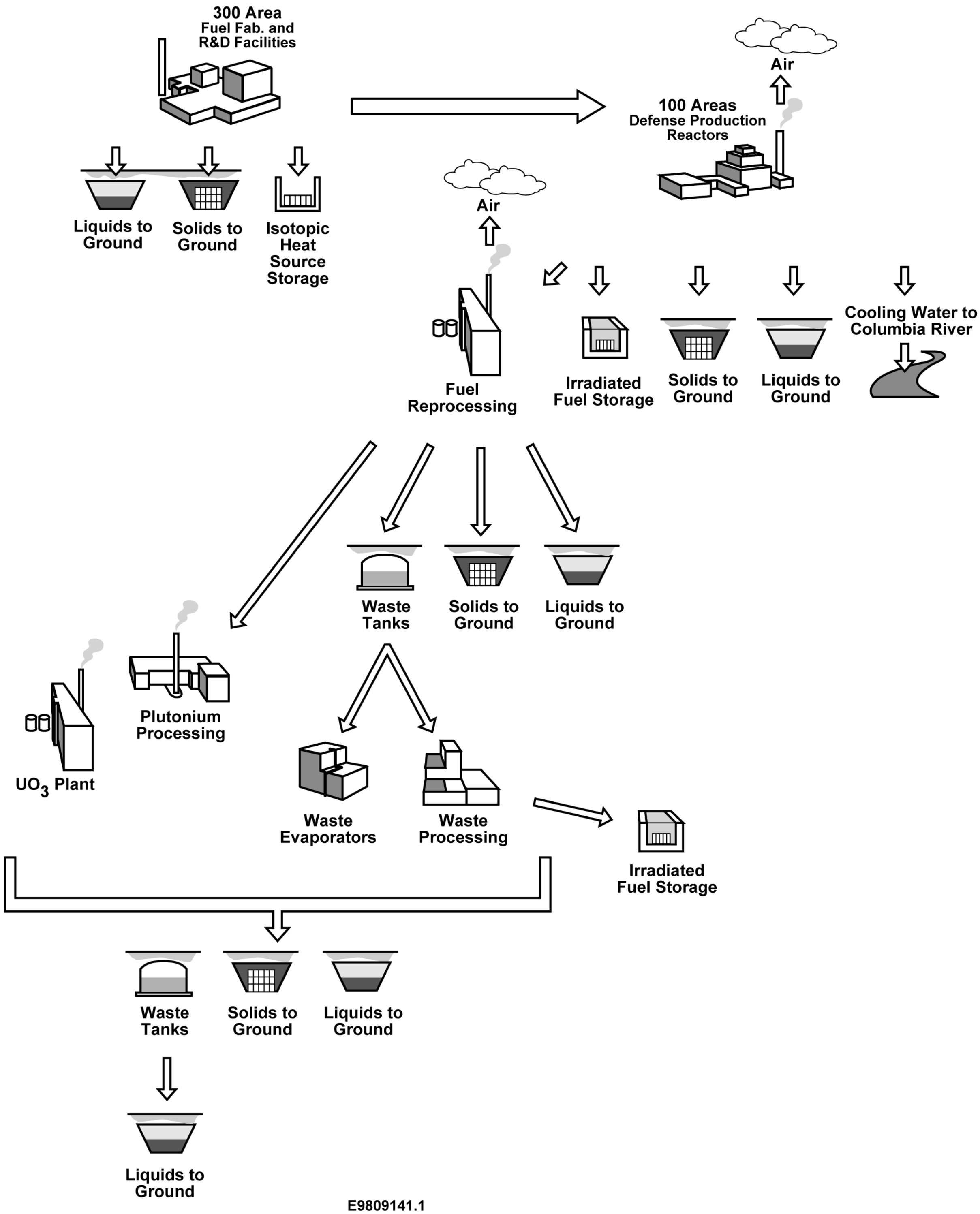
Inventory is the total quantity of radiological and chemical constituents used and created at the Hanford Site, and their distribution in facilities, waste disposal sites, the vadose zone, groundwater, and the Columbia River ecosystem. Understanding inventory is key to a credible system assessment, because the potential groundwater and river contamination is proportional to the amount of radionuclides and chemicals that are disposed on the Hanford Site and capable of migrating from the Hanford Site. The technical information that defines an inventory at a moment in time includes the location and quantity of the waste, and the contaminant concentrations and physicochemical characteristics of the radionuclide and/or chemical compounds. Location and quantity are essential to forecasts of the relative position of contaminants, their migration pathways, and the magnitude and duration of their release. Contaminant concentrations and waste characteristics are needed to support the release estimations.

A holistic (i.e., mass balance) approach to quantifying site inventory is central to the inventory technical element scope. To date, inventory estimates for radionuclides and hazardous chemicals have been developed within specific projects for specific wastes. These estimates tend to be conservatively high, with respect to those contaminants included, and represent only a fraction of all Hanford Site waste sites. The Groundwater/Vadose Zone (GW/VZ) Integration Project is the first project with a mandate to develop a comprehensive analysis that compares and reconciles the estimates for each facility with estimates of the total Hanford Site inventory.
A comprehensive integrated analysis will ensure that estimates for key contaminants are sufficiently accurate and credible to support a sitewide assessment of environmental impacts and risks.

Because the long-term configuration of the waste inventory depends on future remediation and land-use decisions, a baseline estimate of end-state inventory distributions must be defined for a system assessment. The system assessment is examining the 1,000-year period following site closure. Thus, the current Hanford Site setting must be known, then remedial, decontamination and decommissioning, and disposal alternatives can be implemented when they are scheduled to occur on the time line leading to site closure.

The vast majority of the radioactive waste inventory at the Hanford Site was created during the production mission. A conceptual model of the Hanford Site operation during the production mission is shown in Figure A-1. There were three distinct steps in the production process: fuel fabrication, fuel irradiation, and chemical separation. During the first decades of production work at the Hanford Site, it was common to locate waste disposal sites relatively close to waste-generating facilities. This practice resulted in numerous and varied disposal sites. The most dangerous radioactive wastes were stored in large single-shell tanks (SSTs) in the 200 Areas

Figure A-1. Conceptual Diagram of Hanford Waste Generation Process.



(Agnew 1997, Kupfer et al. 1997). Large volumes of solid waste (e.g., contaminated tools and protective clothing) were disposed in burial grounds, and large volumes of liquid waste were discharged to shallow subsurface cribs, french drains, injection (or reverse) wells, and specific retention trenches. More recently, all fuel fabrication and reactor operation activities ended and cleanup of past-practice units began in the 300 and 100 Areas. Low-level waste (LLW) from ongoing operations is disposed in specific burial grounds in the 200 West and 200 East Areas. Most liquid discharges of radioactive wastes have been discontinued, an exception being tritium disposal to the State Approved Land Disposal Site, which receives treated water from the 200 Area Effluent Treatment Facility (ETF). Tritium is discharged by permit to this facility because it is not removed during treatment.

To determine an inventory estimate at a moment in time (e.g., now or at site closure), one needs to amend Figure A-1 to include two aspects. First, the quantities of radionuclides and chemicals imported and exported from the Hanford Site are introduced or extracted at several points in the operation (e.g., materials fed into the fuel fabrication process, chemicals fed into the reactor operation and chemical separation processes, and uranium and other special nuclear materials left the Hanford Site). Second, the figure presents the production mission, and needs to be overlaid with the current cleanup mission. Decisions regarding the remediation, decontamination and decommissioning, and disposal actions will impact virtually all facilities and wastes depicted in Figure A-1. These cleanup actions will define the end-state configuration (i.e., both location and stability or form) of the wastes.

Thus, inputs to the estimation of inventory involve the following:

- Imported and exported radionuclides and chemicals
- Processes and their waste streams for fuel fabrication and research, reactor operation, and chemical separation
- Waste transfers and manipulations (e.g., evaporation)
- Remedial, waste stabilization, and disposal actions consistent with the forecast end-state of the Hanford Site.

Records and databases describe what is known of disposals to solid waste burial grounds and discharges to liquid discharge sites. The Office of River Protection (ORP), maintains a best-basis inventory assessment of the wastes in SSTs and double-shell tanks (DSTs). The best-basis inventory is based on results of the Hanford Defined Waste (HDW) model, tank waste characterization data, and tank waste transfer knowledge. The projection of inventory for the System Assessment Capability (SAC) (Rev. 0) will rely on information and data from these databases, the best-basis ORP inventory, and a science and technology effort directed to incorporate additional waste streams into the HDW model.

An objective of the inventory technical element is to develop the methods for representing wastes in appropriate locations, in appropriate amounts, and at appropriate times. The locations, amounts, and times should be based on knowledge of the imports and exports, the processes and waste streams, the remediations to be performed, and the uncertainties in each.

A.2 EXISTING DATABASES AND CONCEPTUAL MODELS

Radionuclide inventory records are maintained, and estimates were made for waste sites containing large fractions of some contaminants at the Hanford Site. A total radionuclide inventory estimate was established on the basis of records of Hanford Site reactor fuel production and chemical separation operation (Watrous and Wooten 1997). It is considered to be reasonably accurate; however, the distribution of inventory among the various waste sites and facilities that received waste streams is less certain and for some sites unknown. A companion sitewide Hanford Site inventory of potential groundwater contaminating chemicals has not been established.

Some databases are an assembly of disposal records (e.g., the Solid Waste Information Tracking System [SWITS] database). SWITS is a database of the disposal records for all solid waste burial grounds dating from the beginning of Hanford Site operations. Its contents are limited to information contained in written records, and these existing records emphasize a few radionuclides of greatest interest at the time the records were generated (e.g., cesium-137, strontium-90, uranium isotopes, and plutonium isotopes). Recent records are being influenced by waste acceptance criteria, which draw attention to the highly mobile and long-lived radionuclides of greatest threat to human health (e.g., selenium-79, technetium-99, iodine-129).

Other databases represent a merging of model results, field observations, waste measurements, and process knowledge (e.g., the best-basis inventory of tank wastes). It merges results of the HDW model, the tank waste characterization data, and process knowledge to reach a best-basis inventory estimate.

A.2.1 Tank Waste

Several efforts have been made over time to estimate tank waste radionuclide and chemical inventories. Most recently, a best-basis estimate was completed for the current inventory in SSTs/DSTs (Kupfer et al. 1999). This estimate is based, in part, on results from the HDW model (Agnew 1997), on tank waste characterization data on solids and liquids, and process knowledge. The HDW model also estimates tank waste inventories discharged to cribs and leaked from tanks. Numerous tank characterization reports are available that record sample and analysis data. Tank Waste Information Network System 2 (TWINS2) is an internet data access interface and architecture, which provides access to several relational databases containing Hanford Site waste tank characterization data. The following databases are used:

- Tank Characterization Database (TCD). The TCD is a comprehensive relational database of solid and liquid phase OPR characterization data. Within TCD, estimates of tank inventory are based on the following:

  - Historical Tank Contents Estimate (HTCE)
  - Tank Characterization Report (TCR)

– Best Basis Inventory: basis is indicated as one of the following:

S - Sample concentration from the tank of interest

M - HDW model concentration data

C - Calculated from other analyte data (e.g., yttrium-90 from strontium-90, barium-137 from cesium-137, uranium isotopes from UTOTAL, OH from charge balance, alpha isotopes from total alpha, etc.)

E - Derived from engineering assessment or process knowledge, including application of sample data from other tanks of interest.

- Tank Vapor Database (TVD). The TVD contains tank headspace characterization data obtained after 1992.

The TWINS2 interface allows the user to extract data from databases and return data to the user's web browser, in ASCII format, to be loaded into a spreadsheet program for viewing and analysis.

The ORP, River Protection Project (RPP) (formerly the Tank Waste Remediation System [TWRS] project) has developed a global inventory of tank wastes based on process history (Kupfer et al. 1999). This independent estimate is derived primarily from essential material procurement records, from various chemical flowsheets used to reprocess Hanford Site reactor fuels, and from calculations of radionuclide generation and decay. The global inventory complements and supplements the best-basis inventory described earlier by providing an alternative basis for comparison. The global inventory estimate involved a thorough review of all pertinent sources to identify errors, biases, inconsistencies, and missing information. The data sources include sample analyses, process flowsheets, waste transaction records, reactor fuel data, and essential material records. Kupfer et al. (1999) provides a global inventory for 25 nonradioactive components that comprise more than 99% of the total tank waste mass, estimates for 4 other minor chemical components, and global estimates for 46 radionuclides. To ensure that inventory values resulting from the evaluations are technically defensible and reproducible, the original source of assumptions, data, and background information are thoroughly documented.

A.2.2 Solid Waste Burial Grounds

The SWITS database (Clark 1995) is a compilation of all records for buried transuranic-contaminated waste and low-level radioactive waste disposed in solid waste burial grounds at the Hanford Site. This database is updated as waste is disposed. Inventories for both inactive and active burial grounds are recorded. Both radionuclides and hazardous chemicals are tracked in SWITS. The completeness of the records decreases for earlier disposed wastes. Radionuclide estimates are provided for all disposed waste, but chemical inventories are generally unavailable for waste disposed before 1980, and are only marginally available between 1980 and 1987.

The SWITS database is the "record" and not an "estimate" of the contamination disposed. Until recent times, the record was limited essentially to cesium-137, strontium-90, uranium isotopes, and plutonium isotopes. Thus, methods of extrapolating these records to additional isotopes of interest are essential if the potential risks and impacts from solid waste burial grounds are to be estimated.

A.2.3 CERCLA Remediation Sites

Inventory estimates for *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) sites were developed from process knowledge, and from sampling and analyses of site materials. CERCLA sites include cribs, ponds, and ditches in the 100, 200, and 300 Areas; decommissioned buildings (reactors, processing plants, auxiliary structures); and inactive solid waste burial grounds. Minimal radionuclide and chemical inventory data exist for many sites, and the process of collecting more detailed inventory information at specific sites is dependent on the remediation schedule. Recent CERCLA efforts have concentrated on the most contaminated sites in the 100 and 300 Areas.

The Waste Information Data System (WIDS) contains the official summary of the history and status of Hanford waste sites. WIDS provides access to information concerning each of more than 2,500 potential waste sites at the Hanford Site.[1] WIDS supplies a description of the site, location, operational process conducted at the site, start and end-dates for waste disposal, contaminants, cleanup activities, and comments, as well as hazards, dimensions, references, and regulatory information. WIDS references the primary sources of data, including inventory data. Among the sources are the SWITS database and the record of radionuclide inventories for liquid discharge sites. All of the hazardous chemical data in WIDS is extracted from Stenner et al. (1988), which was a elicitation of expert opinion.

Diediker (1999) recently updated and published the inventories for 100 and 200 Area liquid discharge sites. Diediker has compiled data from the Crib Waste Management (CWM) database and the annual effluent reports published since 1975 into the Environmental Release Summary (ERS) database. He has subsequently applied decay corrections. The Diediker (1999) publication represents an interpretation of all known data. The publication reports total volume of liquid discharged, years of service, and inventory derived from either sample collection and analysis of the influent or characterization of soils after the waste site was inactive.

[1] Potential sites include those classified "accepted" (solid waste management unit), "rejected" (not a waste management unit) or "discovery" (not enough information) sites. After remediation or subsequent investigation, a site may be reclassified ("Closed Out", "Deleted from NPL", "No Action", or "Rejected").

A.2.4 Hanford Facilities

A variety of facilities containing hazardous and radioactive materials exist at the Hanford Site. These facilities range from 90-day waste storage buildings to the large canyon facilities in the 200 Areas. The WIDS database maintains information on inactive facilities, and only a few key active facilities. The inventories of these facilities are being characterized to prepare for final disposition decisions.

The graphite cores of production reactors are currently undergoing decommissioning. The C Reactor was the first production reactor in the U.S. Department of Energy (DOE) complex to be placed in safe storage in a facility shielding the reactor core from the environment for up to 75 years, or until final disposition. Similar closure activities are planned for the other production reactors. Final decisions on the operation or closure of the Fast Flux Test Facility (FFTF) are expected this year. Activation products and lead, cadmium, polychlorinated biphenyls, and asbestos are the primary contaminants of the older reactors. The known inventories in the graphite-moderated reactors were based on core samples from D Reactor, which were extrapolated to the other reactors based on their comparative size and operation levels (Miller and Steffes 1986).

The 200 Area processing facilities are contaminated with materials specific to their chemical processing activities. Detailed quantitative information on the hazardous and radioactive materials in the buildings is lacking in the inventory database.

Decommissioning of support buildings is being completed. The buildings are typically decontaminated then removed or destroyed and buried in situ. As decommissioning activities progress, the support building inventories will change because of the removal of decontamination wastes.

Tunnels exist in the 100 and 200 areas. The 100 Area tunnels, sometimes noted as caves, are located in 100-C, 100-H, 100-KE, and 100-KW Areas and were used to hold retired rods and other reactor equipment. Currently, the 100-KE tunnel is empty. The inventories of the other 100 Area tunnels are unknown. The 200 East Area contains two tunnels at the PUREX facility. The equipment contained in the tunnels is known, but the exact contents of the equipment in these facilities are unknown. For example, a potentially significant unknown is the iodine-129 activity inside the silver reactors located in a PUREX tunnel.

Basins were constructed to hold process, cooling water, and spent fuel pools. The open basin inventories appear to be well characterized. A number of basins were buried in situ, with or without disposal of additional waste from other sites. Process and cooling water basins were typically used to hold water to determine if radioactive concentrations were above or below the then-current open release thresholds. Chemical contamination information for the basins, expected to be minor, is not known.

The 300 Area facilities were used for research and development activities and nuclear fuel fabrication. The inventory database lacks much information for the 300 Area facilities.

A.2.5 US Ecology's Commercial Low-Level Waste Disposal Site

US Ecology operates one of the few commercial low-level waste disposal sites in the United States on land permitted to Washington State. The site is located south and west of the southwest corner of the 200 East Area. Information about the projected future inventories of materials in this site were obtained from the Washington State Department of Health staff currently preparing an environmental analysis of the site for licensing reasons (DOH 1999). The inventories are generally smaller than those from Hanford Site operations, but their record keeping and projections have the same limitations as the DOE Hanford Site. In particular, the estimated inventory of uranium in the US Ecology site is questionable; it comes to thousands of tons of uranium, which in all likelihood is not really present. This portion of the inventory estimate is so uncertain that the state staff did not provide the estimate.

A.2.6 Other Production or Total Inventory Estimates

In addition to waste site information, total radionuclide production estimates were also made based on reactor operation history. Also, other waste streams are present at the Hanford Site that are planned to be disposed offsite (e.g., unprocessed spent fuel from N Reactor currently residing in K Basin and transuranic [TRU] waste currently stored and scheduled for reprocessing and shipment to the Waste Isolation Pilot Plant). No attempt was made to estimate total site inventories of hazardous chemicals.

Other than project-specific inventory estimates, the most recent attempt at radionuclide inventory estimates across projects was made to support the Composite Analysis (Kincaid et al. 1998). This effort compiled all existing waste site inventories in the 200 Areas. This document illustrates the inconsistencies in inventory estimates from a partial Hanford Site-wide perspective for a few key radionuclides that were demonstrated to be important based on past performance assessments and other studies. Two other studies (Kupfer et al. 1997, Schmittroth 1995) are key references for the inventory compiled for the Composite Analysis.

A.2.7 SAC Scoping Study

A scoping study was performed for the Project. A preliminary SAC inventory database was created for the needs of the scoping study. An initial screening was made on the basis of half-life and quantity created. Radionuclides with a half-life of less than 5 years or for which less than 1 curie was generated were omitted in the database. The remaining constituents were entered into the database. Of the approximately 2,600 waste sites on the Hanford Site identified and tracked in the WIDS, only about 10% have inventory information. WIDS is undergoing a significant update in the next 3 years and inventory information may improve. At present the identified inventory comprises nearly all of the mass expected to be on the Hanford Site. This initial inventory was based primarily on WIDS and TWINS inputs.

A.3 INVENTORY CONCEPTUAL MODEL PROPOSAL FOR SAC (REV. 0)

This section begins by portraying how materials and wastes moved at the Hanford Site during the earlier mission of materials generation and the current mission of cleanup. The conceptual model for the SAC (Rev. 0) inventory is based on rules for combining data and model results, for aggregating sites, and estimating unreported inventories. These types of rules are described. A subset of radionuclides and chemicals for examination in SAC (Rev. 0), consistent with the inventory scoping study, are presented. The conceptual model description concludes with a summary of the output required from the inventory module, the waste site groupings suggested for an inventory model and how they relate to aggregation, and the role of future waste management options.

A.3.1 The Flow of Materials and Wastes at the Hanford Site

The objective of the inventory technical element or assessment is to determine where, when, and how much radionuclide and chemical inventory was available for release to the environment. Generally, one wants to know this at a moment in time such as today or at the time of Hanford Site closure. Figure A-1 provides a basis for describing the flow of materials and wastes. Ideally, the model of the Hanford Site inventory would include the introduction or import of materials, the movement of materials (e.g., fuel and wastes) around the site, the creation of materials in reactors, their chemical separation and associated waste streams, and the export of materials. One hypothetical approach to the inventory model problem would have four steps; mass balance of 1) 300 Area inputs, processes, wastes, and exports; 2) 100 Area inputs, processes, wastes, and exports; 3) 200 Area inputs, processes, wastes, and exports; and 4) future remedial, waste stabilization, and closure actions.

The flow of materials would begin with the import of materials, including radionuclides and chemicals to the 300 Area. Fuel would be either imported or fabricated onsite. Waste streams from the fuel fabrication and research laboratories in the 300 Area would be accounted for in the model. One would basically perform a mass balance on the 300 Area operations and show the major exports to be fuel for the production reactors and wastes to be disposed in the central plateau. Wastes disposed of or stored in 300 Area burial grounds, and discharged to cribs or trenches, would also be accounted for in the model.

A mass balance would then be performed on the 100 Area operations. The history of reactor operation would feed this element. Imported fuel and chemicals would be quantified. That history would include the dates and energy levels of reactor operation, information on fuel failures, chemical treatment of single-pass and N Reactor cooling waters, discharges of cooling waters and fuel failure contamination, and routine reactor operational discharges. The ORIGEN2 model would be used to forecast the generation of special nuclear materials and other radioactive byproducts. The model of the 100 Area operation would create a listing of the time, quantity, and quality of discharges to the environment and discharges of fuel to the chemical separations areas on the central plateau or other facilities for a cool-down or storage period. Wastes disposed of or stored in the 100 Area burial grounds, and discharged to retention basins, cribs, french drains, and trenches, would be accounted for in the model.

The flow of materials and the generation of waste and export products would also be estimated for the central plateau. Imports of chemicals and radionuclides to the 200 Areas and neighboring disposals (commercial low-level waste, environmental restoration disposal facility) would be introduced to a central plateau model. The processes of chemical separation, uranium recovery, cesium and strontium removal, and their waste streams would be used to estimate the wastes produced. Waste transfer records would be used to describe the flow of waste and its present day location. A capability exists to estimate the tank wastes within the central plateau (i.e., the HDW model) (Agnew 1997). This model and professional judgment were used to assess the inventory of tank wastes in individual tanks, discharges to cribs, and losses to the environment from tank leaks. All wastes disposed of or stored in the 200 Area burial grounds, and discharged to cribs, ditches, ponds, french drains, reverse wells, etc., would be described in the model. Residuals in facilities would be estimated. Past exports of plutonium for weapons production and uranium for recycling and future exports of high-level and transuranic wastes to offsite repositories would be subtracted from the Hanford Site inventory.

Another step in the estimation of the inventory would be the development and application of rules that translate the present situation into a Hanford Site closure setting. All *Comprehensive Environmental Response, Compensation, and Liability Act* cleanup wastes in the 100, 200, and 300 Areas are disposed in the Environmental Restoration Disposal Facility trench. Thus, the remediated fraction of the inventory in 100, 200, and 300 Area remedial action sites would move to the Environmental Restoration Disposal Facility. The residual inventory would remain in the environment at the original site. Similar transfers of waste inventory arise in the decontamination and decommissioning of facilities, including the production reactors, canyon buildings, and tunnels. A significant step in the translation of the current setting to a stable closure is the recovery, separation, solidification, and disposal of tank wastes. Rules are needed for the amount of waste recovered, the fraction to remain as a residual, the fraction in low-activity waste and high-level waste, and the other waste streams returned to the DOE.

The overall inventory model would provide an estimate, including uncertainty of the present location, quantity, and composition of the radionuclide and chemical inventory. Application of the remediation and closure rules would yield projections of inventory at times of interest. Corresponding to the time of Hanford Site closure, the inventory model would yield a final inventory used for long-term risk and impact assessment.

A.3.2 An Approach to SAC (Rev. 0) Inventory Estimation

The inventory at the Hanford Site is large and complex and, in some cases, poorly characterized. The modeling framework outlined earlier is ambitious and impractical for SAC (Rev. 0). Too much information must be assembled or estimated to support such a near-term modeling effort. As a result, the GW/VZ Integration Project will rely on a simplified representation of the inventory to perform the SAC (Rev. 0) assessment. The proof-of-principle analysis will obtain performance information needed to design and assemble the SAC (Rev. 1) capability. The Rev. 1 capability will be designed to use the inventory information that will be available for future revisions of the SAC.

The simplified approach to be developed for the SAC (Rev. 0) must merge a variety of inputs: databases of disposal records, databases of inventory estimates, and model results. However, the project faces a choice of approaches to estimating inventory in the future. The project could use a model-based inventory estimate. Such a decision would commit the project to develop, maintain, and history match a model-based inventory. An alternate approach could be the development and maintenance of a best-basis inventory for the entire site inventory (i.e., the merging of various sources of information and data). The former approach implies a structured logic that will admit readily the generation of uncertainty estimates. The latter choice implies an effort that weighs more heavily the professional judgment based on field observations and recorded events that a model has been unable to capture.

For SAC (Rev. 0), the approach taken will be a first attempt of the best-basis estimate. It will be a simplified approach to merging database and model results. The simplifications will take the form of the following:

- Developing rules for combining database and model results

- Developing rules for aggregation of inventory for release and migration simulation

- Developing rules for estimation of inventories not reported

- Developing rules for extrapolation of inventories to include contaminants not reported in the original record or current estimate

- Selecting a subset of radionuclides representative of a range of mobilities in the environment, and selecting a subset of chemicals representative of organic compounds and hazardous metals.

These approaches are described in Sections A.3.2.1 through A.3.2.5.

A.3.2.1 Rules for Combining Database Entries and Model Results. Database entries and model results will be valued equally. The entries will be summed and normalized to the total inventories for radionuclides and chemicals. The inventory data and information will be categorized by operational area and waste type. Estimates and extrapolations of unreported radionuclides and chemicals will be included (see Sections A.3.2.1.3 and A.3.2.1.4).

A.3.2.2 Rules for Aggregation. To achieve an economical but meaningful initial sitewide simulation, the inventory sources will be aggregated by operational area, by contaminant mobility, and by waste types. Waste types are proposed for aggregation because each waste type has a specific release model. By aggregating the inventory, the assessment will be able to identify fewer specific points where wastes are introduced to the aquifer. At these points in space, contaminants of a given mobility in the environment and having a given release model will be aggregated to create a single time-varying release. By collecting the inventory information by waste type, the available information and data will be used to evaluate and incorporate an approach to quantify uncertainty.

To enable the examination of issues related to near-shore releases and plumes, as compared to those from the central plateau, the analysis will include releases from one of the 100 Areas and the 300 Area, and both the 200 West and 200 East Areas. Releases on the central plateau will be further subdivided, as necessary, to better reflect the observed migration of contaminants through the vadose zone and the unconfined aquifer. Thus, the central plateau region may be represented by up to 3 zones within or adjacent to each of the 200 Areas.

Waste types or sites will be aggregated by their release model. Distinct release models for the initial SAC are limited to those for the following:

- Solid waste and contaminated sediments (soil-debris model)
- Tank residuals
- Glass waste forms
- Wastes in cement products or concrete
- Graphite cores of production reactors
- Naval reactor compartments
- Liquid releases of fluids to the vadose zone.

Fluid releases will be further subdivided based on their unique characteristics (e.g., pH, organic content, salt content).

The interface from the inventory to the release module will provide the mass of contaminants (location, mass, characteristics) being disposed at the Hanford Site beginning in 1944. In those cases where data are lacking, inventory may be approximated as being a combination of the mass in the environment (e.g., tritium in the groundwater in 1979), and the mass released from that date forward.

A.3.2.3 Rules for Estimation of Inventories Not Reported. The WIDS database of Hanford's contaminated sites does not report an inventory for the majority of its nearly 2,600 sites. While some have been cleaned up, have no significant inventory, and are no longer sites of interest, others should be included in a cumulative assessment. An accepted means of estimating the potential inventory is necessary.

Assume waste disposals and discharges can be described both in terms of the waste stream characteristics (e.g., cells 5 and 6 wastes from B Plant), and the release to the environment (e.g., valve failure in a junction box); waste sites with known and unknown inventories can then be grouped by event and waste stream. Further, assume that those for which inventories are available are representative of the entire class of disposals or discharges represented by all similar events and waste streams. One can then estimate the nonreported disposals/discharges using the data and information available for the class.

This approach, when combined with aggregation, mass balance and uncertainty considerations, yields a less uncertain characterization of the unknown inventory. That is, while the inventory of each individual waste site is highly uncertain, the uncertainty of the aggregate inventory of all similar waste sites is bounded by mass balance considerations.

A.3.2.4 Rules for Extrapolation of Inventories to Include Contaminants Not Reported. Because much of the inventory record at the Hanford Site is limited to a few key radionuclides, methods are needed to extrapolate to other nuclides of greater risk and impact concern. Many of the older records are limited to cesium, strontium, uranium, and plutonium because of their significance with regard to special nuclear material production and waste storage and disposal.

A method of extrapolating from cesium-137 to other potentially significant radionuclides was developed and applied in the study of solid waste burial ground disposals (Wood et al. 1995, 1996). The assumption was made that the abundance of radionuclides in waste streams going to solid waste burial was identical to the abundance of radionuclides in fuel. The fuel would be aged to correspond in age with the waste stream derived from the process under consideration. The amount of the nuclide included in the disposal record (i.e., cesium-137) would be used with the ratio of the key nuclide (e.g., technetium-99), to cesium-137 in the aged fuel, to calculate the amount of the key nuclide in the disposal. Certainly, the operation or chemical separations process knowledge will be reviewed to ensure use of a "fuel-ratio" method is relevant (i.e., it is reasonable to expect the other radionuclides of interest to follow the nuclide in the disposal record [e.g., cesium-137]), or be bounded by the estimate achieved.

A.3.2.5 Subsets of Radionuclides and Chemicals. The initial SAC will examine a limited number of the more significant radionuclides and chemicals. A complete range of contaminant mobility will be included, thus enabling the results to be extrapolated to radionuclides not modeled, but for which an inventory estimate can be made. A small group of mobile radionuclides and chemicals are known to be of primary interest relative to long-term groundwater contamination because they have already contaminated the unconfined aquifer and are known to be chemically mobile. Tritium and technetium-99 represent the most mobile of these contaminants. They move with the groundwater. Iodine-129 and uranium isotopes exhibit some retardation in Hanford Site groundwater, and are, therefore, in a class assigned somewhat lower mobility. Other radionuclides that are likely to be less mobile, but present in groundwater due to direct injection, are cesium-137, strontium-90, and plutonium isotopes. Cesium and strontium are found generally to be relatively immobile in groundwater while observations at the Hanford Site indicate plutonium is highly immobile. Chemicals of overall interest include carbon tetrachloride, trichloroethylene, nitrite, nitrate, cyanide, and chromium.

For the initial SAC, attention will be directed toward four classes of radionuclide mobility and two hazardous chemicals. The classes of radionuclide mobility are highly mobile radionuclides (e.g., tritium, technetium-99), somewhat less mobile radionuclides (e.g., iodine-129, uranium), immobile radionuclides (e.g., cesium-137, strontium-90), and highly immobile radionuclides (e.g., plutonium). Chemicals selected for study are limited to the two highest impact hazardous chemical contaminants: the organic compound carbon tetrachloride and the inorganic metal chromium.

Total radionuclide inventories generated in the production reactors at the Hanford Site and processed through Hanford Site separations plants were estimated using the ORIGEN2 code (Croff 1980, Wittekind 1994) and the DKPRO code (Schmittroth and Wootan 1997). The results were produced by Watrous and Wootan (1997) and are presented in Table A-1 for those previously-mentioned radionuclides. As a total inventory, these values omit the inventory of fuel generated at the Hanford Site, but not processed through the separations plants. The omission includes any portion of failed fuel assemblies discharged from the production reactors and not recovered and reprocessed, and the fuel that resides in the K Basins. The estimated range of carbon tetrachloride (CCl_4) discharged to its three primary disposal sites is between 570,000 and 920,000 kg (Rohay 1999). An estimate of total inventory for chromium is not available at this time.

Table A-1. Total Radionuclide Inventories Generated and Processed, 1944 – 1989.

Mobility	Radionuclide or Chemical	Curies[a]
Highly mobile	Tritium, H-3	2.3755E+05[b]
	Technetium, Tc-99	3.3151E+04[c]
Mobile, but somewhat sorbed	Iodine, I-129	6.4114E+01[b]
	Uranium, U-232	3.0180E+03[d]
	Uranium, U-233	1.1719E+04[d]
	Uranium, U-234	3.5607E+04[d]
	Uranium, U-235	1.4679E+03[d]
	Uranium, U-236	1.1737E+03[d]
	Uranium, total U	5.2986E+04[d]
Immobile	Cesium, Cs-137	1.2015E+08[e]
	Strontium, Sr-90	1.0392E+08[f]
Highly Immobile	Plutonium, Pu-239	3.7212E+06[d]
	Plutonium, Pu-240	6.7853E+05[d]
	Carbon tetrachloride, CCl_4	5.7E+5 to 9.2E+5 kg
	Chromium (Cr^{+6})	Not available

[a]All radionuclides in curies, decayed to January 1, 1994; chemical units are noted.
[b]Values for tritium and iodine represent total activity in fuel and, as such, do not account for significant portions of these nuclides that were routed to dissolver offgas streams or plant condensate streams.
[c]Values for technetium represent total activity in fuel and, as such, do not account for a small fraction of technetium that may have been extracted during fuel separation.
[d]Values for uranium and plutonium isotopes represent total activity in fuel and, as such, do not account for the relatively large fraction of these elements that were extracted during fuel separation operations.
[e]Values for cesium, (i.e., Cs-137), do not include the inventory of Ba-137.
[f]Values for strontium, (i.e., Sr-90), do not include the inventory of Y-90.

A.3.3 Output of the SAC (Rev. 0) Inventory Module

The inventory technical element will provide the release module with aggregated inventories at a few points in space, for a few representative radionuclides and chemicals, and a representative suite of waste types. However, data provided by the inventory technical element to the release module will go beyond simple reports of curies of radionuclides or kilograms of chemicals. Information on operational history, including dates of facility operation, facility dimensions, including depth and areal footprint, the volume of disposal, and the assumed time of closure, will be included. In addition, a description of the facility's physical end-state will include mention of anticipated stabilization efforts and cover design or performance.

A.3.4 Waste Site Groupings for Inventory Estimation

The SAC Inventory Scoping Study described in Section A.2.7 attempted to break the waste sites into groups by historical, operational, and chemical similarity. In general, the WIDS database identifies all Hanford waste sites and facilities. To better manage the 2,592 sites in WIDS, each site was categorized under one of the 44 types listed in Table A-2. Although each WIDS site was given one of these types, not all sites fit neatly into any one category. Best judgment was used in those instances. The waste release mechanisms are also identified in Table A-2. The release mechanisms do not define the waste-type aggregation. The release mechanisms and chemical characteristics will be combined to define the actual waste-type aggregation. For example, many of the sites are listed as liquid discharge release mechanisms; however, several types of liquid waste exist. The release and migration of the wastes depend on the waste characteristics including pH, organic content, and salt content.

Table A-2. SAC Inventory Waste Categories and Waste Release Mechanisms. (2 Pages)

Categories	Sources in 100/200/All Other Areas			Waste Release Mechanisms
	100	200	All Other	
Physical Plant				
1A Miscellaneous contaminated structure	X	X	X	SW, C
1B Tunnels	X	X		SW, C
1C Fuel storage basins	X		X	SW, C
1D Reactor cooling water storage basin	X			SW, C
1E Reactor structures with cores	X			GC
1F BiPO4 process		X		SW, C
1G U extraction process		X		SW, C
1H REDOX process		X		SW, C
1I PUREX process		X		SW, C
1J Cs/Sr recovery process		X		SW, C
1K Thoria (PUREX) process		X		SW, C
1L PFP process		X		SW
1M Waste throughput structures	X	X	X	SW
1P Evaporation and waste condensate processes		X		SW
HLW Tanks				
2A Leaking single-shell tank leaks		X		LR, TR, G
2B Nonleaking single-shell tank leaks		X		LR, TR, G
2C Double-shell tanks		X		TR

Table A-2. SAC Inventory Waste Categories and Waste Release Mechanisms. (2 Pages)

Categories	Sources in 100/200/All Other Areas			Waste Release Mechanisms
	100	200	All Other	
High Volume Liquid Disposal				
3A Evaporator and tank condensates		X		LR
3B Plant steam condensate	X	X		LR
3C Plant cooling water crib		X		LR
3D Reactor cooling water crib	X		X	LR
3E Misc. high volume cribs/french drains	X	X	X	LR
3F BiPO4 process waste crib/french drain		X		LR
3G U extraction process waste crib/french drain		X		LR
3H REDOX process waste crib/french drain		X		LR
3J PUREX process waste crib/french drain		X		LR
3K Cs/Sr recovery waste crib/french drain		X		LR
3L Thoria (PUREX) waste crib/french drain		X		LR
3M PFP waste crib/french drain		X		LR
Solid Waste Disposal				
4A Radioactive pre-September 1988	X	X	X	SW
4B Radioactive post-September 1988		X		SW, NRC, C
4C Mixed post-September 1988		X	X	SW
4D Hazardous	X	X	X	SW
4E Inert	X	X	X	SW
4F Low volume/incidental (rad and/or haz)	X	X	X	SW
Miscellaneous and Low Volume Liquids				
5A Laboratory	X	X	X	LR
5B Decontamination liquid effluent to ground	X	X		LR
5C Misc. underground storage tank	X	X	X	LR
5D Misc. liquid ground disposal (low volume)	X	X	X	LR
5E Soil residuals	X	X	X	SW, LR
5F Sanitary sewer	X	X	X	LR
6A Airborne release (non-unplanned releases)	X	X		Not included in SAC (Rev. 0)
7U Unplanned release (non-single-shell tank leak)	X	X	X	To be determined
RR No further analyses	X	X	X	Not included

C = waste in cement products or concrete
G = glass
GC = graphite cores of production reactors
LR = liquid release
NRC = naval reactor compartments
SW = solid waste and contaminated soil
TR = tank residuals

The Physical Plant types (1A-1P) are typically facilities used for an indicated process or function. The 1A (Miscellaneous contaminated structures) and 1M (Waste throughput structures) are similar in that they handled large volumes of radioactive or hazardous materials. The 1A types in the 100 Areas are typically above-ground tanks and outfall structures, and in the 200 Areas there are buildings and 90-day hazardous waste storage pads. The 1M types in the 100 Areas are primarily the underground pipes and pumping stations transporting cooling water to and from the reactor. The 1M types in the 200 Areas are typically diversion boxes and valve pits.

Solid waste disposal sites are described as 4A-4F types according to the waste that was disposed. The numerous open burn pits were automatically assigned a 4F type if hazardous chemicals are known or suspected to have been burned at the site.

Liquid ground disposal sites are given a 3A-3M type or a 5A, 5B, 5D, or 5F type. These liquid release categories do not apply to unplanned releases or single-shell tank leaks. The 3A-3M types are the higher-volume disposals, which are broken out by process or as a miscellaneous stream. The 5A, 5B, and 5F types are specific types of liquid that are typically of lower volumes than the 3A-3M types. Type 5D is a miscellaneous category for lower volume liquid effluents.

The remaining types include the atmospheric releases, unplanned releases, and rejected types. The atmospheric release sites were assigned to facility stacks. Any valid site recognized by WIDS that had a WIDS site type of “unplanned release” was given a 7U type. Further evaluation of these sites might reassign the type as a solid waste landfill type (4A-4F) or a miscellaneous low volume liquid type (5D). However, in the interest of time, these sites were assigned the 7U type by default.

The rejected type (RR) contains sites that were classified as rejected because of their lack of hazardous chemical or radionuclide inventory, or their nonexistence or duplication of another site. Additional sites were given a rejected classification because the site was located on the north or east side of the Columbia River, or because the hazardous chemical or radionuclides were removed.

A.3.5 Future Waste Management Options

The basis for project planning of the SAC (Rev. 0) effort has been an assessment of the Hanford Site Disposition Baseline. The guidance contained in the Columbia River Comprehensive Impact Assessment, Part II, (DOE-RL 1998), which details the requirements for a comprehensive assessment of the river, provides a basis for the definition of the post-cleanup end-state. It is described in CRCIA, Part II, as the Hanford Site Disposition Baseline.

> (the Columbia River comprehensive impact assessment) … “is to be performed maintaining as much consistency as possible with each set of Hanford Site-wide cleanup/disposal decisions and with each subsequent revision. In other words, for the collection of DOE documents which, at any given time, constitutes the approved Hanford Site post-cleanup end state, there will be a corresponding CRCIA assessment of resultant impact.” (DOE/RL 1998, page II-1.10)

> "If no officially recognized end-state plan exists for the overall Site, the (…) analysts will develop with DOE's recommendations, the most credible surrogate end-state information available." (DOE/RL 1998, page II-1.10)
>
> "The requirements in this section call for the Columbia River impact assessment to be consistent with the current definition of the Hanford Site after all cleanup and waste disposal actions are complete." (DOE/RL 1998, page II-A.36)

Clearly, with many decisions yet to be made (e.g., long-term groundwater cleanup, tank waste recovery, carbon tetrachloride contamination in the 200 West Area vadose zone), there is no single collection of DOE documents that constitute the approved post-closure end-state. However, the collection of multiyear workplans for projects at the Hanford Site represent DOE's current assumed surrogate end-state. This set of assumptions is the basis for the life-cycle cost estimate for closure of the site. Use of the post-closure end-state assumptions from the multiyear workplans as the Hanford Site Disposition Baseline for the initial SAC will provide an assessment of post-closure risk and impacts that is consistent with the current life-cycle closure budget. Other closure scenarios, including a "No Action" or limited action scenario, will be deferred until later revisions of the assessment tool.

A.4 DEALING WITH UNCERTAINTY

Although the overall quantities of radionuclides and chemicals generated or used on the Hanford Site are relatively well known, the actual amount in specific waste sites is uncertain. Estimates of uncertainty within waste sites could be handled in several ways.

- A general description of the level of knowledge for each site could be prepared, without quantitation.
- Inventory quantities could be entered only if supported by referenceable data, leaving other sites with no distribution.
- The quantities of contaminants in certain classes of sites could be estimated, without giving site-specific detail.
- Relatively well-characterized sites could be used as surrogates for other sites of similar nature.
- Bounding estimates of the total possible within each individual site could be made.

Because the SAC intends to proceed with an uncertainty analysis, the options that do not give at least a semi-quantitative result do not support this direction. Thus, some method of numerically approximating the inventory uncertainties is required.

Consolidation of individual sites into waste categories based on similar locations and operating histories will reduce the uncertainty of the aggregate inventory for the whole group.

The inventory across all groups has a lower uncertainty. It is anticipated that application in the initial SAC will use a holistic sitewide inventory with relatively small error, which is apportioned to the waste site categories in a manner that allows the individual sites to vary considerably while maintaining the overall mass balance. This can be done with a renormalization step for every realization of the inventory.

Aggregation rules will consider similarity of waste type in so far as this indicates a common release model and environmental mobility. Clearly, the multiple individual sources must be located within a similar geohydrologic environment and be forecast to undergo the same final remediation or closure (e.g., placement of an identical cover or barrier system).

Uncertainties in final waste form and disposition will not be addressed in the initial SAC. Thus, a single realization of the Hanford Site end-state will be examined (i.e., the Hanford Site Disposition Baseline). The nature of the uncertainties will be addressed in future iterations, where other waste disposal scenarios will be evaluated.

There is a need for a publicly-accessible, reviewed database of site inventory information. Databases are not easily adaptable to handling uncertain information. The descriptions of uncertainty may be available in the database as best-estimates with ranges, standard deviations, fractiles, or other descriptors of the distribution of the estimates. However, it is likely that an intermediate processor of some sort will be required to convert the database descriptions into numerical realizations for the SAC modeling efforts.

A.5 WHAT THE CONCEPTUAL MODEL IS DESIGNED TO ANALYZE

For the first iteration of the SAC, the inventory is designed to provide the quantities of hazardous radionuclides and chemicals in Hanford waste sites at the time of Hanford Site closure. The conceptual model will provide this description on a level of resolution sufficient to support the initial SAC, but not on a waste-site by waste-site basis. The initial inventory model will provide input for generalized locations (i.e., 200 East, 200 West, 100-B/C, 100-KE/KW, 100-N, 100-D/DR, 100-H, 100-F, and 300 Areas). For each location, generalized types of waste site will be considered (e.g., tanks, tank leaks, high-volume cribs, low-volume cribs, etc.). A descriptor of uncertainty about the inventory will be provided.

Additional information will also be provided for each waste site category. Each class will have a generalized description of its operating history (time waste disposal began, time it completed, volumes of material emplaced or discharged) and a description of the nature of the barrier assumed to be emplaced (if any). Some information will also be provided to help the modeling of the release technical element and vadose zone technical element. Where readily available, this will include quantities of water disposed along with the wastes, and quantities of nonradioactive or nonhazardous chemicals that might influence transport.

A.6 WHAT THE CONCEPTUAL MODEL IS *NOT* DESIGNED TO ANALYZE

For the initial SAC, concentrations of contaminants of concern currently in the vadose zone, groundwater, and Columbia River will not be maintained in the inventory database. The model approach will be to use the historical rates of discharge and/or disposal to the environment to run the models; this means that the models will be used explicitly to estimate today's conditions, as well as those in the future. This approach will validate the models and simplify the inventory requirements. If this approach were not taken, either each site type would need to be characterized for its initial condition inventory before any analyses, or models would need to be used to estimate the current inventory distribution in the environment.

The inventory database will not contain environmental sample data per se. The gathering of environmental samples may be instigated as a result of gaps in the inventory and uncertainties, but any such data will not be incorporated in the SAC (Rev. 0) inventory database. The task will not require that samples to be obtained. Information from samples may be used to generate inventory information, but the sample data will be held by the Hanford Environmental Information System rather than by the SAC.

A.7 OUTSTANDING ISSUES

A number of weaknesses in the current inventory estimates were identified in this document, and in the S&T Plan for the GW/VZ Integration Project. A number of weaknesses or omissions were also noted during the consolidation of the SAC initial inventory database and its sources.

A.7.1 WIDS

The current version of WIDS does not yet include chemical or radionuclide inventory data. Data that existed before WIDS was revised is still available, and was incorporated during the inventory scoping study. Updates to solid waste burial grounds were made using SWITS data from Anderson and Hagel (1996) (and will be updated directly from more current SWITS data*)*. Updates to liquid disposal site inventories will be updated with information from the latest environmental release system (ERS) database (Diediker 1999).

For many sites, there is no inventory data. In those cases, a generic inventory will be selected based on the type of site, and scaled by the estimated release, based on inventories available for similar sites.

A.7.2 Best-Basis Inventory

The technical approach to developing the best-basis inventory is the strongest found for any Hanford Site cleanup operation. The projections are being based on a combination of monitoring and process history modeling, using all available data. However, even this program has limitations, most of which were enumerated in project reports (Harmsen et al. 1998, Cammann et al. 1999).

The HDW model predicts chemical inventories better than radionuclide inventories due to trace chemistry effects and variables of fuel exposure not captured in the model (MW-days, fuel design, co-precipitation, solubility, complexants, etc.).

A.7.3 Science and Technology

The project's Science and Technology (S&T) program has a task developing inventory estimates for cribs, drains, and other waste types associated with chemical separations and reprocessing wastes. As the S&T program develops information, it will be incorporated by the inventory task.

A.7.4 Background

A topic of interest in the SAC development is differentiation of Hanford Site contaminants and impacts from others in the environment from other sources (e.g., the development of an agricultural industry and a mining industry, and the construction and operation of the Columbia River reservoirs). One approach is to compare projected concentrations from Hanford Site sources to naturally occurring or human-enhanced regional background. A process to develop these background levels in numerous media is required.

A.8 PROPOSED PATH FORWARD

Development of the SAC (Rev. 0) inventory estimate will execute the approach described in Section A.3.2. The inventory estimates developed by core projects as reflected in maintained databases and models will be combined using an unambiguous set of rules. Inventories and contaminants not captured in inventory records will be incorporated into the inventory by applying rules based on similarity assumptions and process knowledge. Inventories of the approximately 2,600 waste sites in WIDS will be aggregated into a few classes of waste release based on their operational area, waste type, and environmental mobility. Finally, the effort for SAC (Rev. 0) will be made tractable by focusing attention on four radionuclide mobility classes (highly mobile, less mobile, immobile, and highly immobile), an organic compound carbon tetrachloride, and an inorganic metal hexavalent chromium.

The Inventory Scoping Study initiated the development of a database of waste sites and their contents. This database is currently incomplete, but efforts are ongoing for improvement and expansion. The basic structure of the Scoping Study database is probably adequate to consolidate available information. However, the database will need continual updating from the WIDS, TWINS, environmental release summary, and other core project databases. Data collection and collation is a major effort with several Hanford Site contractors and Core Projects. The SAC needs to be intimately tied in with the various databases. The Integration Project will identify an appropriate mechanism for cooperation with the various groups involved in data collection, and ensure that new data and interpretations are used in SAC assessments.

A series of simple projection methods are needed to establish future waste inventories for the assumed baseline conditions. These methods will be developed from the existing multiyear workplans for projects at the Hanford Site. These end-state and end-point settings that define the

Hanford Site closure setting will be coordinated with the projects and with the regulatory and affected communities.

The uncertainties in inventory are large. A numerical or rule-based mechanism for implementing the holistic inventory concepts presented in Section A.3 will be developed. This needs to be undertaken in conjunction with the development of the Release and Vadose Zone model implementation, to ensure that the data transfer is appropriate.

An ongoing effort to provide information based on historical operations would be invaluable for the numerous waste sites that now have only a physical description and no information on radionuclide or chemical content. A "data-mining" operation to provide a review of available records and documents on inventory may benefit the SAC and core projects. Such a review could be independent of the initial SAC, but feed information to future revisions.

The project S&T program has instituted development of models for waste disposal to cribs associated with the processing plants. These models must be completed and the results incorporated into the HDW model. The HDW model may need to be adapted to include additional sources (e.g., solid waste disposals, chemical separation plant residues, tunnels, pipe networks, and reactor cores).

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